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EGI Lessons Learned - A Common Thread

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Today I will be presenting questions, comments, issues, anecdotes, and data gathered from testing EGI integration on several different platforms.

There will be questions posed within this presentation

Some are rhetorical, and some can have several different answers depending on the individual platform.

My background is navigation software, integration and test on fixed wing tactical aircraft.

I have spent the last several years testing EGI integration into fixed wing tactical and also rotary wing aircraft.

This presentation is generic since most of the topics discussed are relevant for EGI integration on many platforms.

Different Missions, Different needs

- Performed developmental test on both fixed and rotary wing aircraft with vastly different missions, interfaces, and needs
- Testing resulted in some very common lessons learned.
  - Similar questions
  - Similar performance
  - Similar goals

How often do the batteries need replacement?

Each integration is different and has its own challenges.

Different integrations share common questions, comments and lessons learned.

The questions most often asked are interspersed throughout this presentation.

Performance seen during test is similar

Similar goals - get a newer, more accurate and more reliable product to the fleet.

Questions, Opinions, Concerns

- documentation
- training
- planning
- testing
- problems
- enhancing characteristics

How often does the EGI output bad data during a flight?

The first five are the recurring issues and concerns. All are important.

They are not listed in particular order.

Each will be addressed during the presentation.

The enhancing characteristics are the result of successful EGI integration.

Training and documentation are the foundation for good EGI integration and test. The risk of installing new avionics, controls and displays, and software is partially mitigated by good documentation and training. They also provide a basis for required testing - in the lab, during ground and flight test.

PIDS, and other similar documents provide the rules for integrating the EGI, and specs and TEMPS define what items need to be tested, how the testing will be accomplished, and what the exit criteria are.

Time for test is generally compressed - adding regression testing for new software adds time and money to the program.

Integration and test always have some problems along the way. Documenting problems as soon as they are discovered helps everyone get a clear understanding of what the problem is. Once understood, there are usually several ways to solve a problem.

After testing for a while, and as the test team becomes familiar with the EGI integration, most of the "problems and issues" are replaced by comments such as, "that is really better than the old system", or, "that would have taken a lot more time before".

Documentation

- When should it arrive?
- Where are we without it?
- Why is the documentation always late?
- How is it organized?
- Can it make or break a program?

Why is the EGI worth its weight in gold?

Months before the aircraft arrives, and certainly way before test. All types of documentation - PIDS, ICDs, wiring diagrams, NATOPS, users guides, operator manuals

We are lost without good documentation.

Everyone - engineers, maintainers, and aircrew all need both generic and specific documents.

Sometimes in a rush to get the software out the door for test, the documentation lags. This puts the testers at a disadvantage.

Documentation is what we all need the most during EGI test.

It is difficult for aircrew to write changes to NATOPS while testing system integration.. Using old NATOPS procedures is sometimes a disadvantage when using EGIs, since the EGIs are much more accurate than some of the older nav systems.

There are different levels of documentation. An overview is especially useful at the beginning of a program, while details are needed to fully understand the system and how to best test.

Different personnel, different needs. The maintainer needs good docs that specify such things as torquing procedures, battery changing schedules, wiring diagrams.

Aircrew need information on how to best use the system. That includes training manuals and training. Good docs definitely help a program, and lack of docs hinder test.

Training

- Everyone benefits
  - desktop trainers
  - classroom
  - lab
  - simulators
  - ground test

how long do the gyros take to spin down ?

All personnel involved in test require training!

There are many ways to provide timely training. It can start with good documentation.

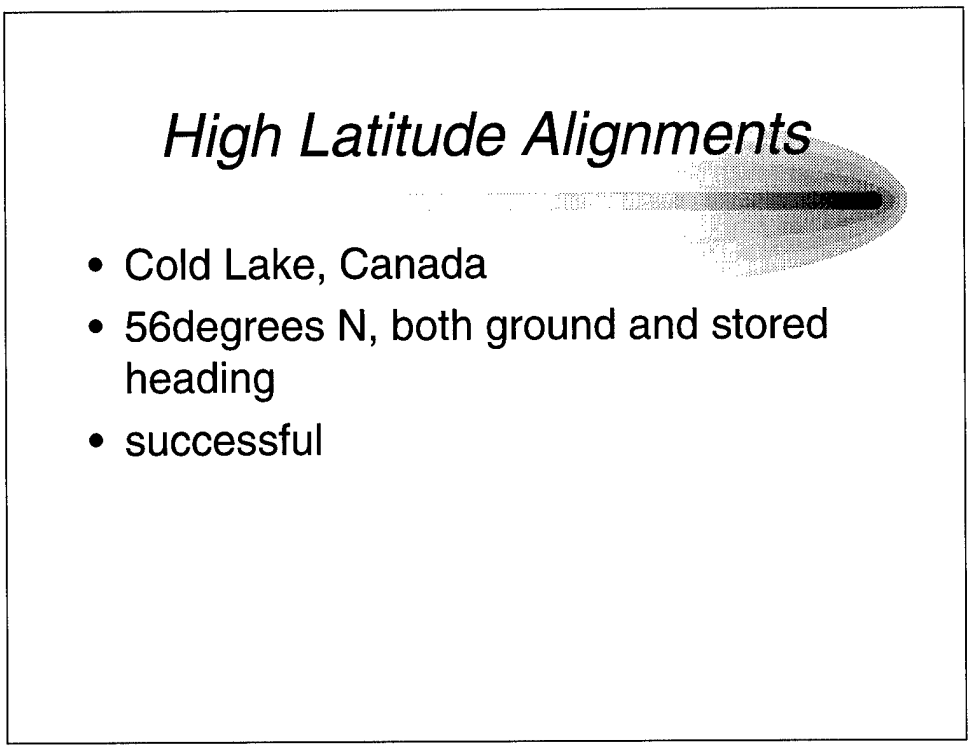
Desktop trainers are very useful because there is no requirement to sign up for a block of lab or aircraft time. Individuals can set their own pace. Trainers are also a good way for maintainers to "see" possible installation/integration issues prior to aircraft hardware installs.

Early classroom training provides a forum to understand the concept of the EGI/aircraft integration and a good time for questions to be answered.

Although labs are never quite work the same as the aircraft, lab time is still a good way to practice data entry, alignments, navigation mode changes, waypoint entry, etc. It is also a good way to find early integration issues.

Simulators are a great way for aircrew to get familiar with data entry, displays, button pushing, and increase their general comfort level with the new system.

Once the aircraft arrives, ground test is essential to determine readiness for flight test, and a pre-verification of system integration.



Aircraft flew from Whidbey to Cold Lake, Canada.

Both Gyro compass and stored heading alignments were performed.

Human Factors

- importance of "user friendly" interface
- aircrew/EGI interface
- ease of data input
- prevention of blunder errors
- minimum heads down time
- data display
  - format, content, alerts

Why does initialization data need to be correct ?

Human factors is the comfortable relationship between aircrew and aircraft.

EGI integration should be as transparent to the user as possible. The mission of the aircraft should take priority - not the EGI. Input and output data should be well organized, easy to access, and easy to understand.

Data input should be logically organized - avoid nested or levels of data entry.

Define early in the program the default hemispheres, if any.

Should input data such as latitude, longitude, date or time default to some pre-determined values? Should data for input be stored just prior to shutdown?

Would an 'are you sure' help prevent blunder errors?

The design of the system should allow aircrew to input only what is required at the time.

Strive to prevent excessive heads down time.

Data displayed needs to have instant impact. It needs to be in readable format (not hex). When a problem arises, we all want to know what the problem is, not wait until the aircraft lands to look up some hex value in a book. (Again, back to documentation). NO ONE wants to look at hex data!!!

When designing alerts, be careful to avoid nuisance alerts. Example, do you inform the aircrew every time GPS aiding is lost? Do you wait 1 minute? Do you wait 10 minutes?

System Design

- Backup nav systems
- system checks
- nav mode changes
- adherence to navigation conventions

It's cloudy today, will GPS work well?

Does there need to be a backup navigation system? How much redundancy does the aircraft need?

Should the different EGI modes or the backup nav system be compared for position and/or velocity differences and should alerts be displayed if a threshold is crossed?

Are EGI navigation mode changes automatic based on validity bits and/or IBIT fails? Additionally, if more than one EGI is installed, does automatic selection for prime also depend on whether one is aligning, and the other is navigating?

Since many aviators fly multiple platforms, adhering to standard navigation conventions and display formats makes sense.

System Design, cont.

- antenna placement
- keying
- loading almanac files
- zeroization

Where are the batteries? What are they used for?

Perform analysis for antenna placement early in the design stage. If multiple avionics or stores require a GPS antenna, does the platform require separate GPS antennas, or would a splitter amp suffice?

Will the EGI be keyed at the box, or from somewhere onboard the aircraft?

Would it be beneficial to load almanac files on some type of 1553 interface? Is it necessary?

Is there a need to connect the EGI to some type of master zeroize switch, or would pulling batteries be sufficient for the platform?

Test Planning

- Be prepared for the unexpected!!!
- Scheduling
- Conflicts
- Flight cards
- briefs
- debriefs

How heavy is the EGI?

The unexpected always happens. Be as prepared as possible.

The best schedule will only remain that way for a microsecond.

When assets are shared, there will always be conflicts for who has priority. Be flexible - everyone is trying to complete their tasks.

Try to generate flight cards that leave no margin for interpretation or you might be surprised at the de-brief. What is clear to you may not be clear to anyone else. Leave lots of room for aircrew comments. We were testing in-flight alignments, and I asked the aircrew to fly straight and level for the first 30 seconds. The result was an entire IFA while hovering. Engineer and aircrew had a different interpretation of straight and level.

At the brief, it is very helpful to have display formats, push button layouts, a list of current integration problems, and NATOPS at hand in case any last minute questions arise.

Debrief as soon as possible after the flight. Ask questions. Ask for comments. Ask whether any problems or enhancing characteristics were observed during the flight.

Data Collection and Analysis

- what data to collect
- what data to reduce
- how to output the data
- inputs for reports

How do you pick the satellites the EGI uses?

Get as much instrumentation as possible. There is never too much data, although it may seem that way. Try to instrument all the data your EGI outputs (1553, synchros, ARINC-429), and all input data into the EGI.

Decide what needs to be processed/analyzed during every flight, and try to automate those procedures.

Inputs, handshakes, validities, mode changes, switch positions and alerts are useful in determining how the EGI is operating.

Aircraft path, altitude, airspeed, attitude and heading are also good clues as to what's happening during the flight.

Alignment time, type, estimated horizontal and vertical error, figure of merit, C/no, and bit status are indicators for how the flight fared.

Try to consolidate data as much as possible. Print output on change only. You will have less data to examine.

Plots are great for the big picture.

Cardinal rules

- Get a good product to the fleet. They are the user
- If it does not work, fix it
- believe everything the aircrew says happened, every time
- there is always an alternative
- you cannot be over-prepared
- each flight is a lessons learned

How many satellites do we need to navigate?

The fleet is the final user. Ensure they get a good product.

Strive to get all the problems fixed, even the annoying ones. It makes life easier for aircrew and maintainers.

No matter how much the system has been tested, there can always be surprises. Always believe what the aircrew says happened during a flight. Use the data, if possible, to determine why it happened.

There are always alternatives, but they are not always obvious. Keep looking.

There is no such thing as being over-prepared.

Every ground test or flight, good or bad, offers valuable lessons learned. Use the results to better the system.

The Good

- The accuracy of the EGI as tested was better than the some of the truth data
- EGI has reduced aircrew workload and improved SA
- precise positioning for jamming and weapons
- Hovering with an EGI is much better than with Doppler navigation systems
- Better en-route navigation
- better time functions
- highly accurate and reliable

What is the drift rate of the INS?

I have used both differential GPS and laser data to verify the accuracy of the EGI.

It is interesting to note that the accuracy of the EGI was better than that of some of the truth data.

There is a reduction of aircrew workload when the EGI is installed.

Hovering using EGI inputs to the automatic flight control system is much more stable than hovering using doppler systems.

En-route navigation is much better due to the accuracy of the EGI.

Time calculations can now be done using EGI data, rather than manually.

The EGI is highly accurate and reliable

Problems

- Lack of satellite acquisition on some GEM cards after extended periods of non use
- occasional problems during alignment
- instrumentation issues with ARINC and 1553

Can we navigate without GPS?

This problem appeared on each of the EGI programs I have worked on. Pulling batteries helped twice, re-loading software helped once, and running IBIT cleared the problem once.

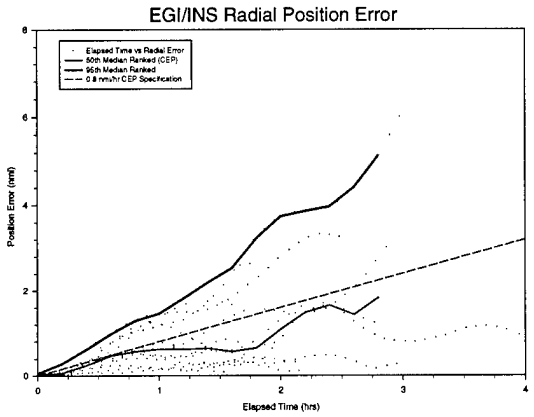
Very rarely, there are various problems that abort or prolong alignment.

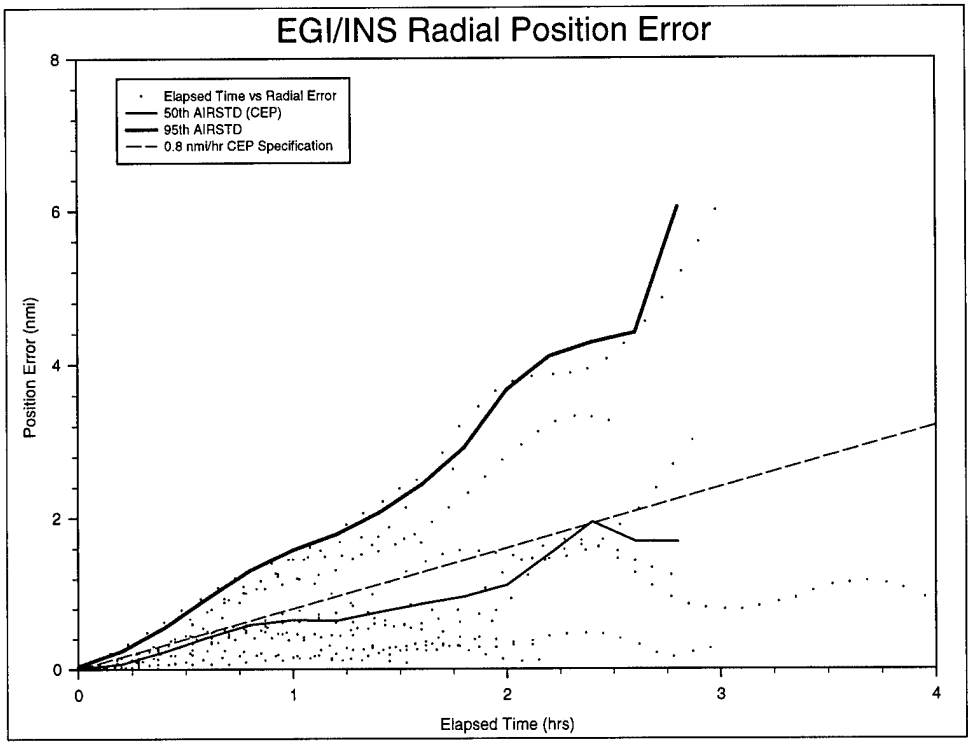
1553 bus problems - Once, the EGI would not power up after several days of ground test. Could not find the problem, even after checking connectors, wiring, and switches. Finally, when attempting to hook up a 1553 bus analyzer, we found the 1553 bus was not terminated properly (as a result of ground test).

Instrumentation system can affect the EGIs ARINC-429. On one program, the ARINC wrap fail and ARINC transmission warning get set when the EGIs are powered on prior to the instrumentation system. The ARINC fails trigger an INU fail. It took a while to convince the aircrew that the EGI was "not broke".

Conclusions

- My experience with EGI integration has:
  - always been interesting
  - occasionally frustrating
  - sometimes an uphill battle

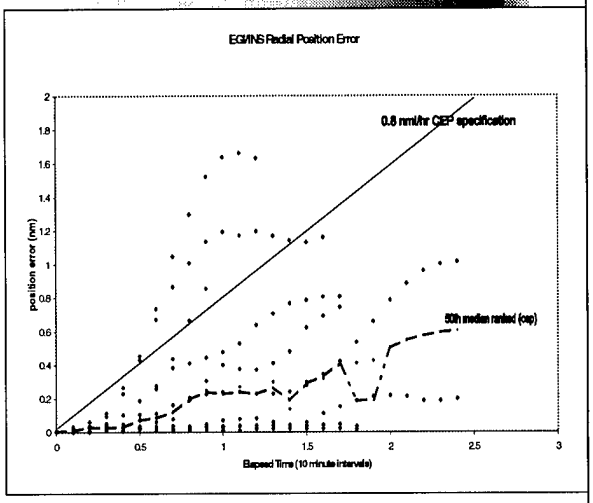


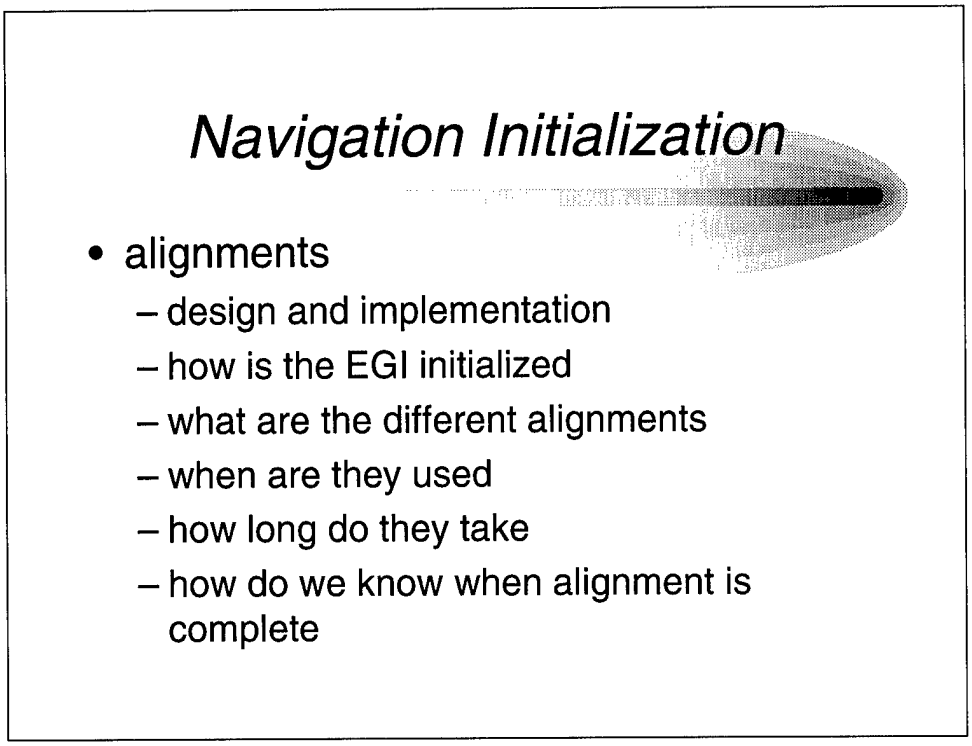

EGI/INS Radial Position Error
Elapsed Time vs Radial Error
50th AIRSTD (CEP)
95th AIRSTD
0.8 nmi/hr CEP Specification
Position Error (nmi)
Elapsed Time (hrs)
0
2
4
6
8
0
1
2
3
4

Conclusions, cont.

- rarely perplexing
- never routine
- constantly 'in motion'

- Thank you!





Alignments are the beginnings of all flights. Make them work - and they only work as well as the data that's input!

Ensure they are implemented correctly.

Design the format for initialization data inputs with no room for blunder errors.

Only allow input data that is necessary for the specific alignment type being requested.

During training, and again in the documentation, be sure to specify what the different alignment types and their subsets are (stationary and in-motion).

Document when to select a specific alignment type.

State how long each alignment type takes to complete.

Talk about satellite acquisition times, and about weekly vs annual keys

Display in easy to read format - alignment time, quality and align complete.

LET there be no doubt that alignment is complete.

Integration

- Issues
  - aggressive test schedules
  - software upgrades
  - lack of aircraft assets
  - regularly scheduled maintenance
  - lack of spares
  - weather

Will the EGI align on a ship ?

Most schedules are compressed - to the right for start of test, and to the left for completion of test. It is very difficult to balance testing needs vs schedules, especially when problems arise.

Software upgrades - What do you do if new software is available during developmental test? Stop testing now, and start over with the new software? Plan to stop when testing can go no further, or at a point where regression test would be greater than the remaining test? There is no single good answer to this question.

If new EGI software is to be loaded, how will that be accomplished?

What happens when the aircraft is down? How do you get back on schedule?

Does the test schedule include aircraft maintenance time?

Are there spares available for the duration of test???

What happens to the test schedule when the aircraft has a day VMC only flight clearance and the weather un-cooperative for extended periods of time?

Do you need to share assets or facilities during test? How do priorities get set?

Integration, cont.

- More Issues
  - testing during "off peak" hours
  - distrust of new technology
  - the rumor mill
  - unusual problems
  - readiness to test

How often does the EGI require calibration ?

When the aircraft is flying during the day, lots of ground test time gets shifted from odark30 to odark30. Can the team support that type of test?

There is an inherent distrust of new technology. Why upgrade to EGIs when the "old" system worked fine? Aircrew, engineers and maintainers all need time to get to understand the EGI integration in their aircraft. Only after time, when integration issues are growing smaller and the EGI seems to be performing as well as, (and better) than the old system, does the distrust slowly dissolve.

Sometimes, problems on one integration cause ripple effects on other integrations. During catapult testing with the EGI, the aircrew came back saying "the EGI broke during cats". They had heard about problems on another platform. What really happened was a keying problem that prevented the EGI from entering into Blended mode, that had nothing to do with cat shots.

Has the problem been seen on other aircraft, or on other platforms?

Unusual problems - GPS week rollover, Y2K, and leap day testing are all behind us now! We sat for several days in a shielded hangar with simulated satellite signals verifying the EGI would continue to operate - and it did, only to be humbled by almanac problems after that fateful August day.

One final question on issues...Is the EGI integration really ready for flight test? How many open problems are there? Are there work-arounds for integration issues? Will the program benefit from flight test